

Ocean Basin Impact of Ambient Noise on Marine Mammal Detectability, Distribution, and Acoustic Communication - YIP

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LONG-TERM GOALS

The ultimate goal of this research is to enhance the understanding of global ocean noise and how variability in sound level impacts marine mammal acoustic communication and detectability. How short term variability and long term changes of ocean basin acoustics impact signal detection will be considered by examining 1) the variability in low-frequency ocean sound levels and sources, and 2) the relationship of sound variability on signal detections as it relates to marine mammal active acoustic space and acoustic communication. This work increases the spatial range and time scale of prior studies conducted at a local or regional scale. The comparison of decadal time series from locations in each of the Pacific and Indian Oceans provides the means for quantifying sound levels and variability on multiple time scales in both hemispheres.

OBJECTIVES

The growing concern that ambient ocean sound levels are increasing and could impact signal detection of important acoustic signals being used by animals for communication and by humans for military and mitigation purposes will be addressed. The overall goal of the study is to gain a better understanding of how low frequency sound levels vary over space and time. This knowledge will then be related to the range over which marine mammal vocalizations can be detected over different time scales and seasons. Over a decade of passive acoustic time series from the Indian and Pacific Oceans will be used to address the following project objectives:

1. **Determine the major sources (or drivers) of variation in low frequency ambient sound levels on a regional and ocean basin scale.**
 - A. What are the regional source contributions to low frequency ambient sound levels?
 - B. Is there variation in source characteristics of the major low frequency source components over space and time?
 - C. Is low frequency sound level uniformly increasing on a global scale?
2. **Investigate the impacts of variation in low frequency ambient sound levels on signal detection range, marine mammal communication, and distribution.**

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- A. How does species specific detection range (acoustic active space) vary on a daily, weekly, monthly, and yearly time scale?
- B. Does the presence of low-frequency cetacean vocalizations relate to changes in ambient sound level?
- C. Do marine mammals exhibit any changes in calling behavior to compensate for noise?

APPROACH

This effort is a comparative study of passive acoustic time series from Comprehensive Test Ban Treaty Organization (CTBTO) locations in the Indian (H08) and Pacific (H11) Oceans over the past decade (Figure 1, Table 1). Patterns of productivity and regional oceanographic processes will be examined over the same time period to ensure appropriate comparisons between locations and over consecutive years. Long term, passive acoustic monitoring will play a crucial role in addressing a multitude of ecosystem questions, as acoustic sensors can operate year round at remote locations to record environmental signals and animal presence in areas that are typically inaccessible to traditional sampling methodologies due to extreme weather or logistical obstacles.

CTBTO monitoring stations consist of two sets of three omni-directional hydrophones (0.002-125 Hz) on opposite sides of an island. Two triads of hydrophones eliminate the acoustic shadow created by the island to ensure full area coverage of an ocean basin. The hydrophones are located in the SOFAR channel at a depth of 600 to 1200 m, depending on location. The hydrophones are cabled to land 50-100 km away and connected to shore stations for data transmission. The ambient noise data is communicated via satellite for 24/7 monitoring to Vienna, Austria. The sites are under the national control of the countries to which the hydrophones are cabled and via AFTAC/US NDC (Air Force Tactical Applications Center/ US National Data Center) for US citizens.

A key question that must be addressed when interpreting passively collected ambient noise is: “Is the variation observed due to a change in the source, or is it due to changes in the acoustic propagation path traveled?” As a consequence, careful analysis is required of changes in the oceanic environment over the same time and space scales of interest. It is anticipated that propagation modeling will employ the use of the Parabolic Equation (PE) technique, though a hybrid method may be more efficient, so both will be examined. The energy trapped in the deep sound channel can be handled efficiently using a number of methods; however the transition from the surface/near surface region must be done with a range dependent model.

The relative and/or absolute spectral level as a function of time can be treated as a time series and analyzed for trends and variability at discrete time scales. Ideally, all the different regional data sets will be calibrated to absolute sound pressure levels (SPL) in standard SI units, removing site-specific hydrophone response, environmental, and propagation characteristics. Comparisons between high and low latitude sound levels will be made by comparing the time series from elements on opposite sides of each island location. Many of the acoustic signals have been well characterized for various species of marine mammals, physical events, and anthropogenic sources such as seismic, allowing for development of automated spectrogram correlation detectors that can be run on long batches of recorded data to detect the presence of sounds produced by particular species or sources (i.e. Mellinger & Clark, 2000, 2006). These automated detection methods make it practical to survey the large dataset proposed in this study which would be prohibitively time consuming for a manual search.

The cornerstone of project success is the appropriate time series analyses and comparisons over time at a single location and across locations. While there is great scientific merit in quantifying the acoustic relationship between physical and biological parameters of the marine ecosystem, the integration of the acoustic datasets with ancillary data sets will further enhance the value of the research by ensuring the appropriate comparisons are made between locations and over time at the same location. Remotely sensed chlorophyll concentration, photosynthetically available radiation, and sea surface temperature will be modeled for the Indian Ocean and Equatorial Pacific. These parameters are input data for the widely used Vertically Generalized Production Model (VGPM) that estimates primary productivity from satellite data (Behrenfeld & Falkowski, 1997). Historical vessel data and movements are available for purchase through Lloyd's Marine Intelligence Unit (MIU). The database extends back to 1997, which is appropriate for obtaining shipping data over the same time periods and scales of the acoustic data and other ancillary datasets.

The exact formulation of the statistical models developed during this research will largely be determined upon examining the available data. However, because it is anticipated that the data will violate assumptions of traditional least squares regression approaches, models that provide more flexibility in model structure (e.g. additive models) and more complex error structures (e.g. temporal and spatial correlation) will be investigated.

WORK COMPLETED

The project began in August 2011. A project planning meeting focused on the data flow and calibration procedures was held in State College, PA and attended by J. Miksis-Olds, D. Bradley, C. Smith (technician), and R. Hawkins (graduate student) in September 2011.

Data from three different CTBTO sites have been downloaded from the AFTAC/US NDC to ARL Penn State. The site locations and data coverage are shown in Table 2. Data continues to be downloaded on a monthly basis to keep the database current. The physical data flow, signal processing and transfer details, and system calibration information was obtained and documented as a first step in being able to calculate absolute sound levels from the CTBTO data (Figure 2). A quality control check was performed on the downloaded and decompressed data to verify proper decompression. Data decompressed at ARL PSU was compared to decompressed data available to the public (Figure 3). The two data streams matched which verified the accuracy of the decompression algorithms.

RESULTS

There are no scientific results at this point. The project is in the early stages of data acquisition and processing.

IMPACT/APPLICATIONS

Quantifying the relationship between factors affecting ocean sound variability and corresponding ecosystem response will illustrate the effectiveness of passive acoustic monitoring for tracking ocean use changes and provide critical information needed for predictive modeling of signal detection probability. The importance of this study is that the statistical details of ambient noise will be quantified over different temporal scales at an ocean basin level, thus extending knowledge gained from local and regional scale studies. Sound level statistics are a critical parameter set when describing noise and are fundamental to reducing the uncertainty of signal detection when applying the

passive sonar equation. The integration of acoustic time series from different ocean basins will provide a synoptic perspective by which to monitor ocean noise in both hemispheres as economic and climate conditions change. The rapid economic growth of India and China is predicted to have a measurable impact on low frequency ambient sound and signal detectability through increased shipping. Results will support the development of mathematical models that predict ambient sound levels from economic growth patterns and shipping statistics. The application of the noise statistics to marine mammal detection and acoustic behavior will illustrate the value of understanding how economic, military, and other geo-political drivers influencing shipping, a dominant component of ocean ambient sound, can impact the marine ecosystem.

TRANSITIONS

This project represents a transition from the acoustic characterization of local and regional areas to the characterization of ocean basins. Detailed knowledge of noise statistics and variation will contribute to reducing error associated with marine animal density estimates generated from passive acoustic datasets, signal detection and localization, and propagation models.

RELATED PROJECTS

Patterns and trends of ocean sound observed in this study will be directly applicable to the International Quiet Ocean Experiment being developed by the Scientific Committee on Oceanic Research (SCOR) and the Sloan Foundation.

REFERENCES

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HONORS/AWARDS/PRIZES

Office of Naval Research Young Investigator Program (YIP) Award – 2011

Table 1. Acoustic sensor location summary. Latitude areas in parentheses under Latitude Region indicate acoustic focus of sensors on opposite sides of island.

Site	Element	Acoustic Focus	System	Location	Latitude Region of Sensor	Major Oceanographic Process
HA08	N	Equatorial Indian	CTBTO	Diego Garcia, UK	Low	Equatorial Current
	S	Indian	CTBTO	Diego Garcia, UK	Low (Mid)	Equatorial Current
HA11	N	W Pacific	CTBTO	Wake Is., USA	Low (Mid)	N Equatorial Current
	S	Equatorial Pacific	CTBTO	Wake Is., USA	Low	N Equatorial Current

Table 2. Data successfully downloaded and available to ARL Penn State.

Site/Location	Start Day	Most Recent Download	# Missing Days	Total Days	Total Years
HA08/Diego Garcia	01/21/2002	06/28/2011	40	3406	9.33
HA10/Ascension Island	11/04/2004	06/28/2011	4	2424	6.64
HA11/Wake Island	04/25/2007	06/28/2011	5	1521	4.17

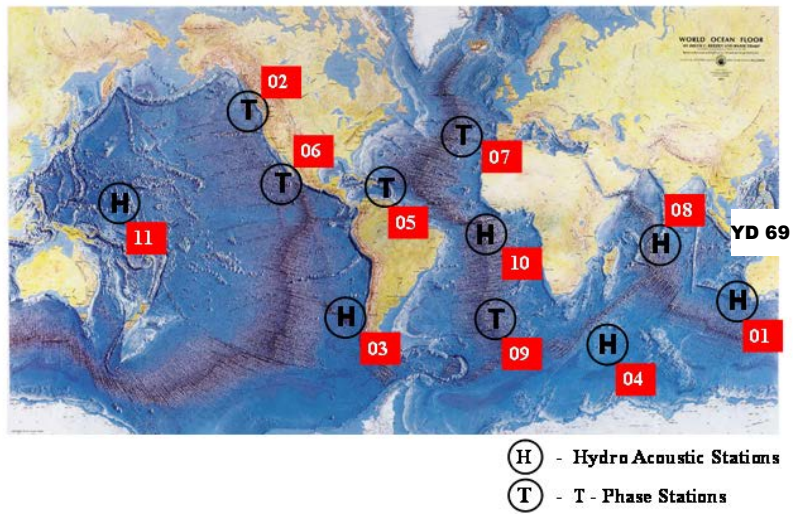
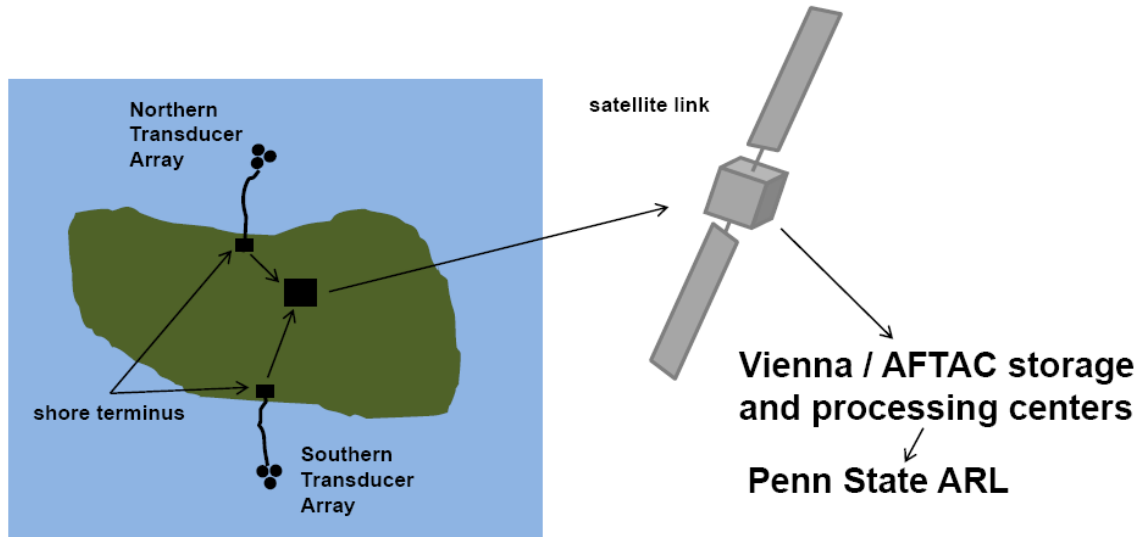


Figure 1. Location of CTBTO Hydroacoustic Sites. H sites denote hydrophone sites, moored in the water column at sound channel depths. T sites denote seismic “T-phase” sensors. This project will use data from H08 and H11.

A)



B)

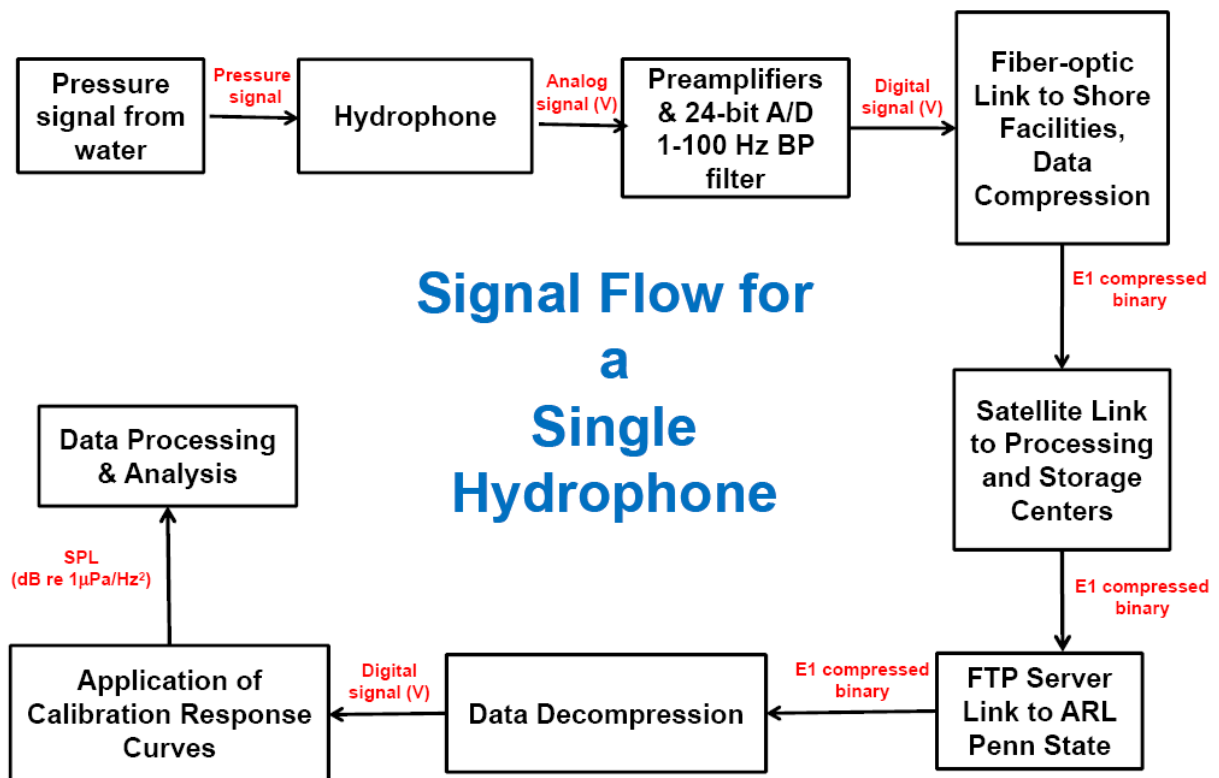


Figure 2. Data flow from the CTBTO hydrophones to ARL Penn State for the A) physical data and B) signal flow. B) The red transfer text between nodes in the flowchart indicates the data format.

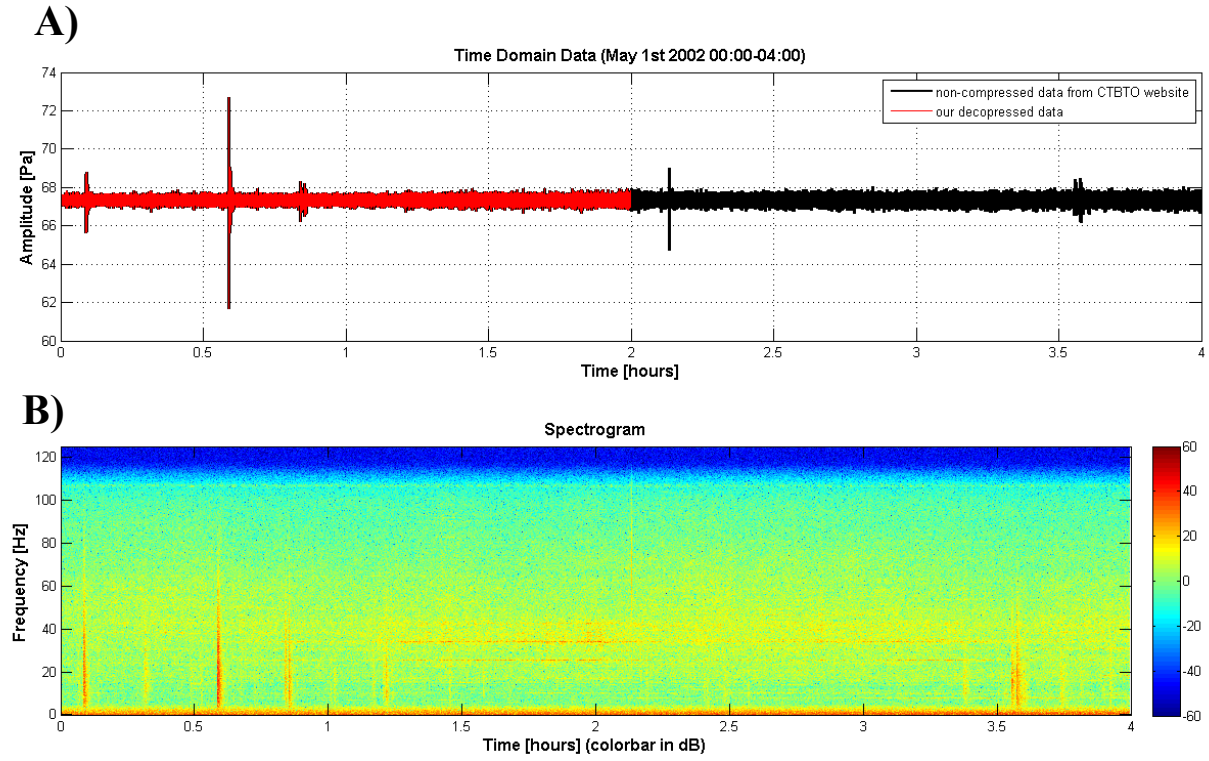


Figure 3. *A) Data comparison of non-compressed data from the CTBTO website and data decompressed at ARL Penn State. Note the difference in line sizes so that the overlapping signals are shown. B) Four hour spectrogram of the decompressed data in A).*